Electromigration Failure in Au and Joule Heating Induced Oxidation in Cu Conductors - Part 2

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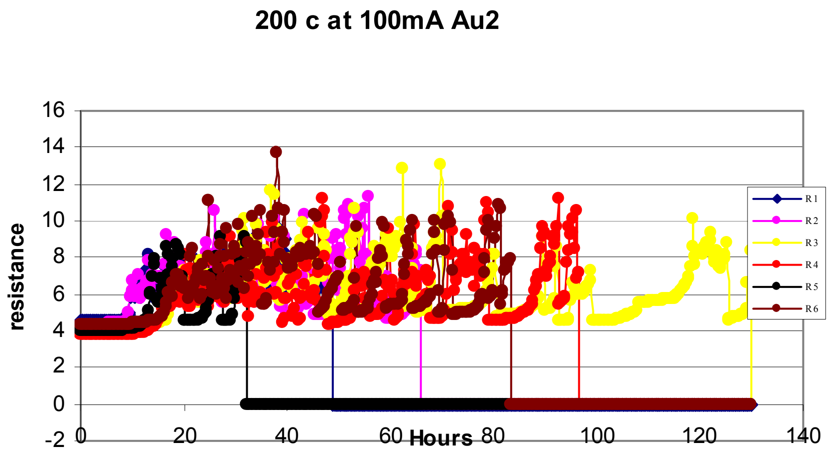
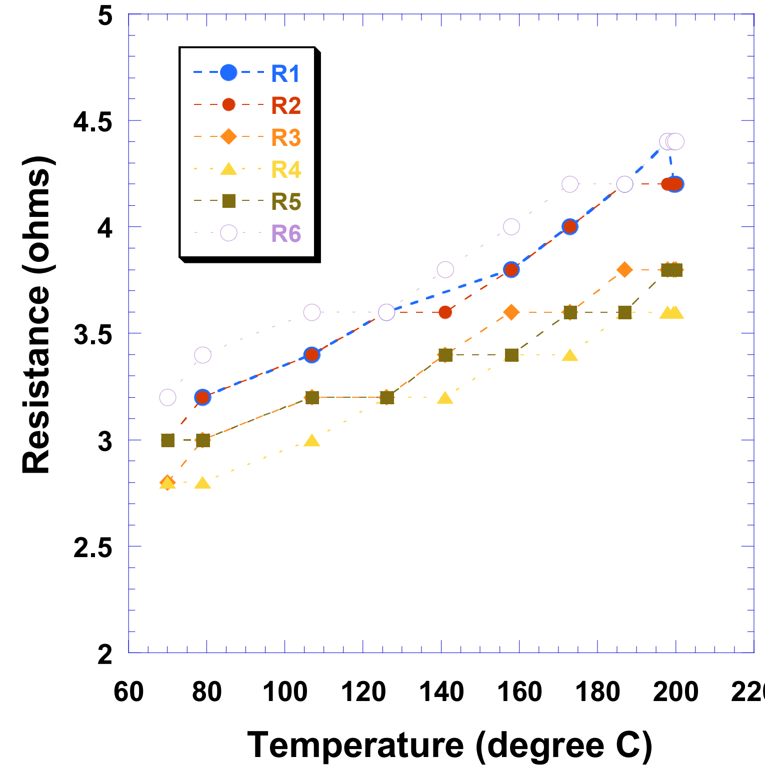
Experimental procedures:

- **Thermal treatments were done for Gold interconnects in environmental test ovens at temperatures of 200°C and 240°C, in air and at one atmosphere.**
- **The Currents used were 500, 100, 50 mA, which correspond to current densities of 9.26×10^5, 1.85×10^5 and 9.26×10^4 A/cm^2.**
- **The increase in resistance with temperature was also monitored, using very small current densities, to ensure that no Joule heating occurred with the test current densities.**

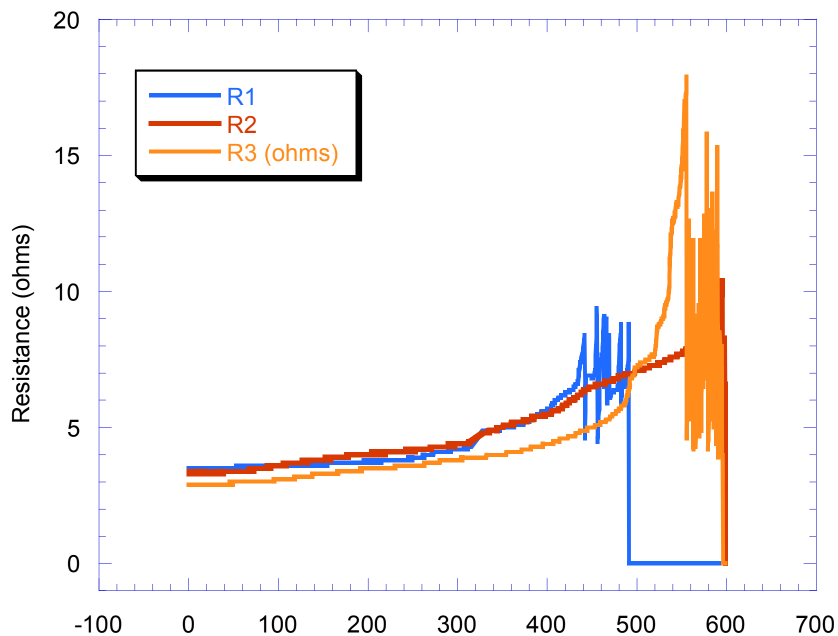
Test Results:



Time vs. Resistance at 200^{o}C and 1.85e5 A/cm^{2} in Au test structure

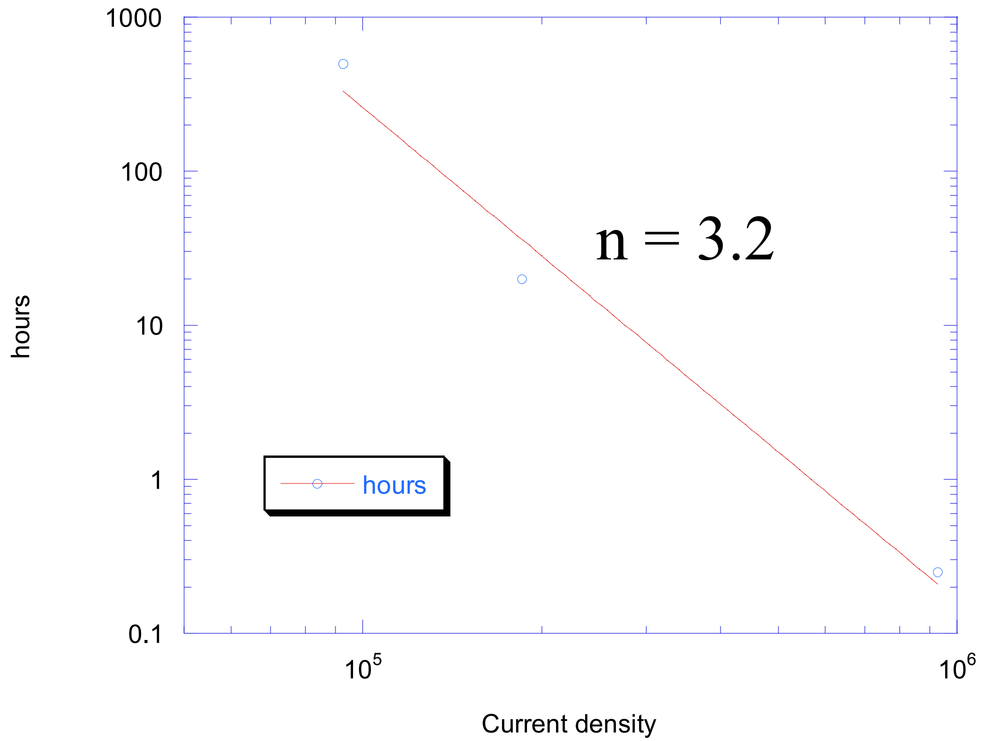


Resistance vs. Temperature in Au conductors using 0.005A



← Time vs. Resistance at 200^{o}C and 9.26×10^{4} A/cm^{2} in Au test structure

Current density vs. time to failure



From the time to failure vs. current density, we can evaluate the value of the exponent for current density in Black's equation:

$$t = A\, j^{-n}\, e^{Ea/kT} = A\, j^{-3.2}\, e^{Ea/kT}$$

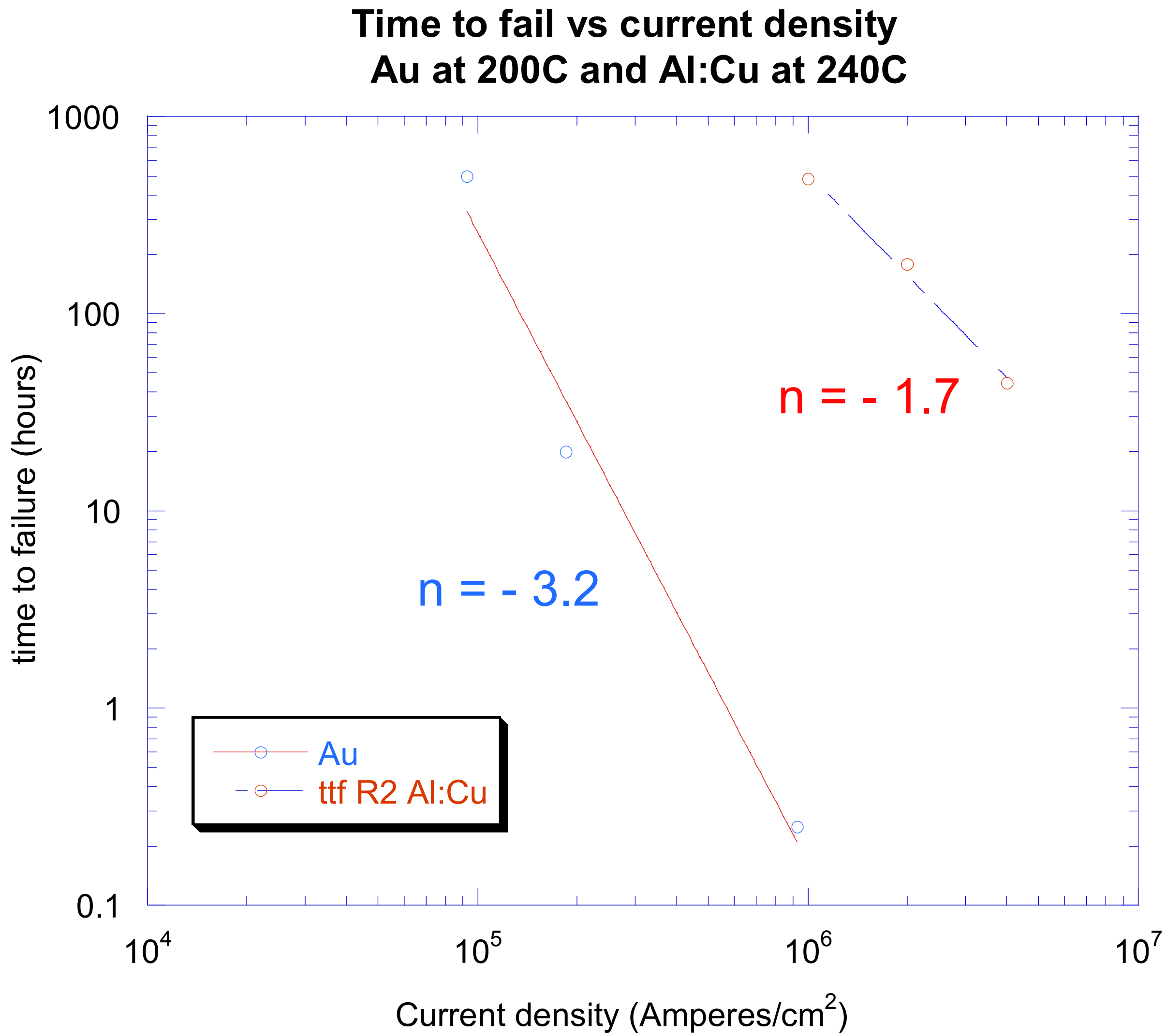
t is time to reach failure (or allowable % degradation)

j is current density

Ea is activation energy (in eV)

k is Boltzman's constant

T is temperature



This graph compares the time to failure as a function of current density for Au SoC structures and commercial Al:Cu structures with tungsten vias. Activation energies for electromigration (Ea in the equation in previous page) could not be determined due to insufficient samples. From these results, a good guess for Ea would be 0.6 or 0.7 eV (as compared for 1eV obtained with the Al:Cu structures)

Failure analysis

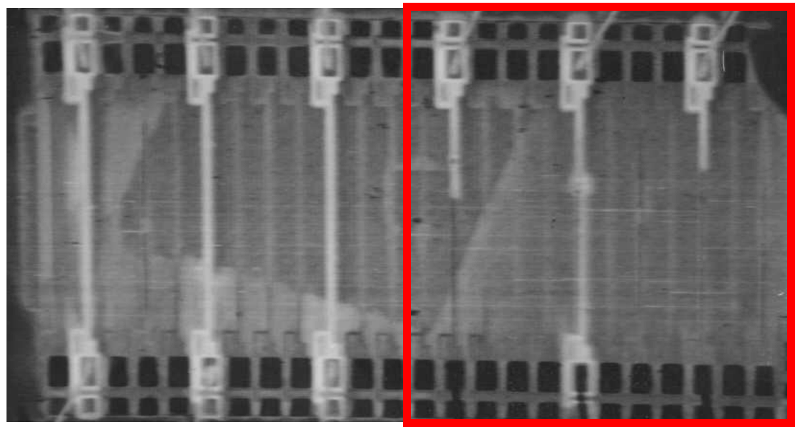
- **Three SEM modes were utilized to identify where the failure occurred:**

Backscattering mode is an interaction between the electron beam and the specimen atoms which results in a change in the primary electrons trajectory and/ or energy.

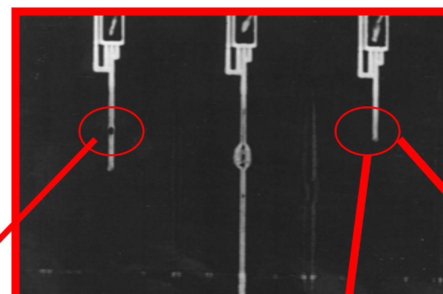
Electron Bean Induce Current (EBIC) represents current flow of electrons passing trough the portion of the semiconductor material "Si02" expose to the primary beam of the SEM.

Secondary Electron mode electrons emerge from the surface of a specimen from the interaction of the primary beam and the specimen.

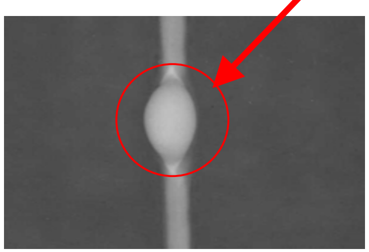
Failure Modes 1 and 2: open circuit due to void formation. Hillock formation is also observed, with the potential for causing short circuits.



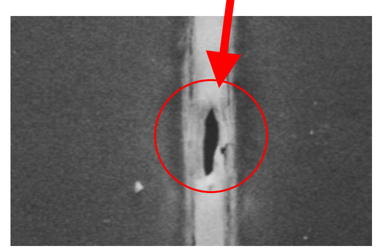
R1 through R6 at 15x, 20 kV, secondary electron mode



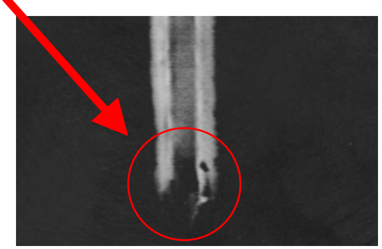
R1, 2, and 3 at 30x, 20 kV, EBIC mode



R3 hillock at 400x, 20 kV, backscattering mode



R3 void at 400x, 20 kV, secondary electron mode



R1 void at 400x, 20kV, EBIC mode